

Claims

- 1 1. A method of fabricating a three-dimensional structure from an etchable substrate, the
2 method comprising the steps of:
3 specifying a unit cell size for a plurality of unit cells, each unit cell corresponding to an
4 area on a mask;
5 generating a plurality of measurement values, each measurement value corresponding to
6 a portion of the structure, each measurement value associated with a specific unit cell;
7 converting the plurality of measurement values to a plurality of unit cell fill factor values;
8 generating a gray tone data set in response to the unit cell fill factor values,
9 the gray tone data set comprising
10 a plurality of distinct rectangular areas and distinct square areas, each distinct area
11 corresponding to a unique gray tone level,
12 adjusting the size and number of square and rectangular areas to increase the available
13 number of unique gray tone levels; and
14 creating the mask in response to the gray tone data set such that at least a portion of the
15 plurality of rectangular and square areas are disposed on the mask.
- 1 2. The method of claim 1 further comprising the step of etching a pattern of non-
2 overlapping three-dimensional photoresist volumes disposed on the substrate, the pattern of
3 photoresist volumes generated in response to the areas on the mask.
- 1 3. The method of claim 1 wherein the measurement values comprise height values measured
2 at specific points on a surface of the three-dimensional structure.
- 1 4. The method of claim 1 wherein the step of converting the plurality of measurement
2 values uses selectivity data, photoresist contrast data, and exposure data.
- 1 5. The method of claim 1 wherein the step of adjusting the size and number of square and
2 rectangular areas comprises calculating at least a portion of the rectangular and square
3 geometries that can fit within a unit cell.
- 1 6. The method of claim 5 further comprising the step of eliminating rectangular and square
2 areas that exceed a specified aspect ratio.
- 1 7. The method of claim 5 further comprising the step of eliminating rectangular and square
2 areas having a dimension smaller than a minimum spot size of a mask write tool.
- 1 8. The method of claim 1 wherein the photoresist volumes are mesa structures.

1 9. The method of claim 1 wherein the gray tone data set comprises shapes that differ in area
2 as a result of an increase in the length or width of the of the shape.

1 10. A method of increasing available graytone levels for use in a lithographic process, the
2 method comprising:

3 determining a unit cell size in response to a designed part geometry;
4 generating a set of distinct quadrilateral areas such that each area fits within a unit cell;
5 removing redundant quadrilateral areas from the set,
6 associating each graytone level with a distinct quadrilateral area; and
7 correlating each graytone level with a distinct unit cell fill factor.

1 11. The method of claim 10 wherein the set of distinct quadrilateral areas comprises a first
2 set of square areas and a second set of rectangular areas.

1 12. The method of claim 10 wherein the set of distinct quadrilateral areas comprises shapes
2 that monotonically increase in area by incrementing the either the length or width of the
3 quadrilateral area by one unit quantity.

1 13. The method of claim 10 wherein all distinct quadrilateral areas that fit within a unit cell
2 are associated with a graytone level.

1 14. The method of claim 13 wherein quadrilateral areas having a dimension smaller than the
2 minimum spot size of a mask write tool are removed from the set.

1 15. A lens fabricated using a grayscale lithographic process, the process comprising the steps
2 of:

3 generating a pattern of three-dimensional photoresist structures on a substrate using a
4 mask, the mask comprising a plurality of regions populated by rectangular and square areas; and
5 etching the photoresist and substrate, thereby generating a lens.

1 16. The lens of claim 15 wherein the lens has a lens diameter ranging from about 5 μm to
2 about 1 cm.

1 17. The lens of claim 15 wherein aspect ratios of the rectangular and square areas are
2 restricted to reduce surface defects in the lens.

1 18. The lens of claim 15 wherein the required smoothness of the lens surface determines the
2 number and size of the distinct square and rectangular areas disposed on the mask.

1 19. The lens of claim 15 wherein a portion of the regions are substantially concentric.

- 1 20. A diffraction grating produced using a lithography process, the lithography
2 process comprising the steps of:
3 generating a mask having a periodic arrangement of a plurality of selectively
4 filled unit cells, each unit cell partially filled with a fractional area selected from a set of
5 square and rectangular areas, each area corresponding to a gray tone level;
6 depositing a photoresist layer on a substrate;
7 exposing the photoresist layer to radiation selectively transmitted by the areas of
8 the mask;
9 developing the photoresist layer such that a periodic arrangement of photoresist
10 mesa structures result; and
11 etching the mesa structures and substrate.
- 1 21. The grating of claim 20 wherein the grating spacing ranges from about 5 μm to
2 about 1 cm.